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Proffered Papers: Brachytherapy 5: In vivo dosimetry

OC-0173

In vivo dosimetry with MOSFETs and GAFCHROMIC films during IORT for Partial Breast Irradiation

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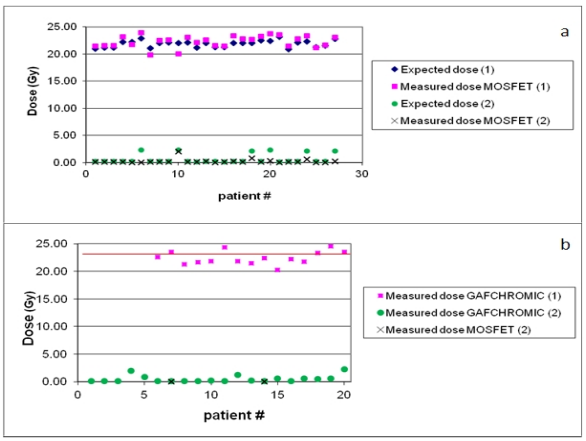
Purpose/Objective: *In vivo* dosimetry is an important tool to check whether the delivered dose conform to the expected dose. For intraoperative radiation therapy (IORT) in partial breast irradiation (PBI), this is especially relevant since the high dose is delivered in a single fraction. The purpose of this study was to compare the given dose to the expected dose PBI.

Materials and Methods: During the period May 2010 - October 2014, 292 elderly (60+) patients, diagnosed with breast cancer (tumour diameter < 3 cm) were treated with IORT in our institution. For 47 of these patients, *in vivo* dosimetry was performed with MOSFETs (metal-oxide semiconductor field-effect transistors, TN-502RD) or/and GAFCHROMIC EBT2 films. PBI with a total dose of 23.3 Gy at 100% (21 Gy at 90%) was given during the operation according to the method described in the ELIOT study (1). All patients were irradiated with electron beams generated with an IORT dedicated mobile accelerator (Mobetron, INTRAOP, USA). The *in vivo* dose measurements were done by attaching the first MOSFET detector under the bolus at the end of the applicator and the second detector attached behind the protection plate (6 mm aluminium plus 3 mm copper), which was used to shield the thorax. During the dose measurements with GAFROMIC films, the first and the second films were placed before and behind the protection plate, respectively. Calibration of the MOSFET detectors and the GAFCHROMIC films was done by measuring the absolute dose with a Roos type ionization chamber. The calibration measurements were performed with the electron beams of the Mobetron in a homemade PMMA phantom at the depth of dose maximum for each energy.

Results: The results of *in vivo* MOSFET dosimetry for 27 patients and GAFCHROMIC film dosimetry for 20 patients are shown in panels (a) and (b), respectively. The measured with MOSFETs entry dose for the breast tissue agrees within 1.7% (SD 3.7%) with the expected dose. The dose measured with GAFCHROMIC films in breast tissue (before the protection plate) was within 3.7% of the prescribed dose. The dose measured with the both methods behind the protection plate was within 2 Gy.



Conclusions: *In vivo* MOSFET and GAFROMIC film dosimetry during IORT was successful for PBI. The results of both methods are in a good agreement. The measured entry dose for the breast tissue agrees within 1.7% with the expected dose. For both methods, the dose to the thoracic wall and lungs was lower than 2 Gy even if 12 MeV was applied.

1. M. Intra, A. Luini, G. Gatti, *et al*, Surgery (2006) 140:467-71.

OC-0174

Real-time in-vivo dosimetry for HDR prostate brachytherapy

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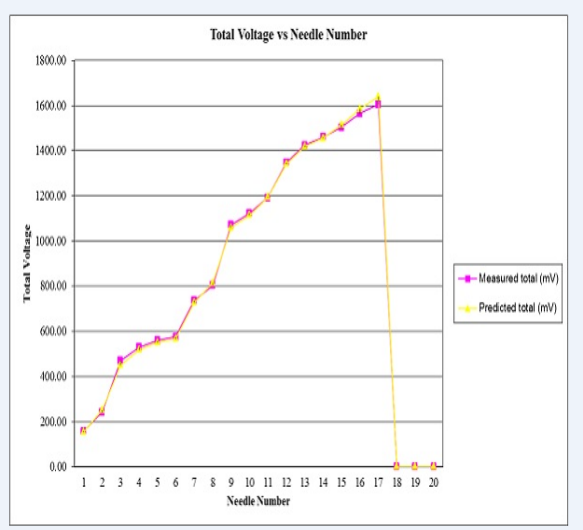
Purpose/Objective: To commission a real-time in-vivo dosimeter service using a Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET) for High Dose Rate (HDR) prostate brachytherapy and then apply it to assess ten clinical patients.

Materials and Methods: The MOSFET detector (Best® medical Canada) together with the reader (microMOSFET, TN-502RDM-H) was used at standard bias setting. A Flexitron® HDR treatment unit (Elekta AB, Sweden), along with an ultrasound (US) based commercial brachytherapy treatment planning system Oncentra Prostate, (Elekta AB, Sweden), were used.

Commissioning tests included linearity, calibration, reproducibility, anisotropy (azimuthal and polar), temperature dependence and energy dependence. Following commissioning, MOSFET measurements were performed for ten patients in real time under trans-rectal ultrasound image guidance, delivering a 15 Gy single fraction to 100% isodose. The MOSFET was inserted using an additional needle with the clinical dose point position chosen centrally in a low dose gradient area. The treatment planning system (TPS) dose was exported and the correction factors applied to predict the measured voltage of the MOSFET. Correction factors included a distance dependent energy correction factor and a calibration factor which converted the TPS dose to the predicted measured voltage. The best fit used for the calibration factor was the power fit which is made up from repeated measurements of the calibration factor.

Results: The MOSFET responds linearly with dose, over the clinical dose range (0.01 Gy to 20 Gy), with R^2= 0.9991. Anisotropy azimuthal and polar resulted in a minimal

dependence within the uncertainty of the measurements; hence no azimuthal and polar correction factors were applied to the measurements. No temperature dependence was found within the uncertainty of the measurement. The measured patient plans were in good agreement with the predicted voltage of the dosimeter with the minimum and maximum percentage differences between the measured and the predicted of -2.6% and -11.3% respectively. Further investigation of the causes of these differences and of per needle dose measurements to allow real-time error detection is still ongoing. Total uncertainty budget of this study was 9.97% for k=2. An example of a clinical patient result is given in the figure.



Conclusions: Our study has demonstrated that implementation of real-time in-vivo dosimetry for HDR prostate brachytherapy using a MOSFET is feasible. Gross error detection is possible when the MOSFET is placed in a low dose gradient and appropriate correction factors are applied.

OC-0175

In vivo rectal dose measures compared to planned and reconstructed doses in US-based HDR prostate brachytherapy

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Purpose/Objective: To study if real time *in vivo* dosimetry, performed on the rectal surface with MOS*kin* detectors included on the trans rectal ultrasound (TRUS) probe, may evaluate possible discrepancies between calculated and delivered doses during US-based HDR prostate brachytherapy.

Materials and Methods: MOS*kins* are a specific type of MOSFET dosimeter, optimized to measure dose in steep dose gradients. Their sensitive volume, defined by the volume of the gate oxide, is 4.8 x 10^{-6} mm^3. In this study, two MOS*kin* dosimeters were calibrated and assembled on the surface of a TRUS-probe, used for real time on-line treatment planning in HDR prostate brachytherapy. During the treatment, the TRUS-probe was left inside the rectum and real time measures of the delivered dose were performed over 14 treatment sessions (prescribed dose to the target surface: 14Gy).

Measured doses were compared to the doses calculated by means of the treatment planning system in the estimated detector position both on pre-treatment images (*i.e.*, acquired 1-2 hours before treatment and used for treatment planning) and on post-treatment images (*i.e.*, acquired within 3 minutes after treatment). In the latter case, the delivered dose distribution was retrospectively reconstructed and assumed as the reference.

Results: Comparison between planned, reconstructed and *in vivo* measured doses, in terms of average absolute differences and maximum discrepancies, are given in the following table.

	Average absolute dose difference <|ΔD|>	Maximum absolute discrepancy
Planned vs reconstructed dose	5.1% ± 2.9%	14.2%
MOS*kin* vs planned dose	6.7% ± 4.9%	18.2%
MOS*kin* vs reconstructed dose	3.8% ± 2.1%	7.8%

Data reported in the table shows that the highest accordance resulted between MOS*kin* readings and doses obtained on reconstructed plans, suggesting that in particular cases in vivo dosimetry might be a better instrument to estimate the dose to the rectum rather than the original treatment planning system itself.

Comparing pre- and post-treatment images, it can be demonstrated that the high observed discrepancy between treatment and reconstructed plans is mainly due to anatomical variations of the prostate shape (*i.e.*, prostate swelling with expanding inter-needles distances) and position (*i.e.*, shift towards the rectal wall). This discrepancy correlated with the treatment planning time.

Conclusions: Doses delivered to the organs at risk during HDR prostate brachytherapy might differ significantly from what is calculated in the treatment planning phase, providing the need for *in vivo* dosimetry in this particular radiotherapy application. MOS*kin* dosimeters integrated to the TRUS-probe proved to be an accurate instrument to perform real time measurement of the dose delivered to the rectal wall. The use of the dosimeters was incorporated in our department into clinical practice, actions protocol are still under study to potentially use the information acquired on-line.

OC-0176

Urethral in vivo dosimetry in HDR prostate brachytherapy with Ir-192 and Co-60 sources

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